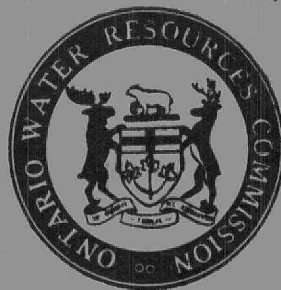


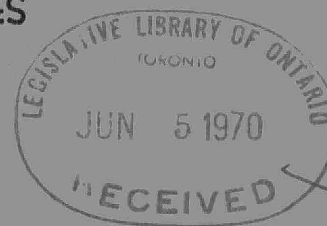
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THE
ONTARIO WATER RESOURCES
COMMISSION



STATUS OF ENRICHMENT
OF
SILVER LAKE

1969

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STATUS OF ENRICHMENT

OF

SILVER LAKE

1969

by

M. F. P. Michalski

and

G. W. Robinson

Biology Branch

December 1969

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SUMMARY AND CONCLUSIONS

Classical indications of accelerated enrichment in Silver Lake were higher concentrations of total phosphorus, free ammonia and Total Kjeldahl Nitrogen in the hypolimnion than in the epilimnion, a positive mid-depth oxygen maximum owing to corresponding abundance of the blue-green algae Anabaena and Aphanothece, and the occurrence of moderately high levels of Chroococcus, Aphanothece and Rhabdoderma between the thermocline and the surface.

To determine how much of the current productivity in Silver Lake is attributable to artificial (man-made) enrichment would require further study. Nonetheless, inputs from surrounding cottagers are undoubtedly contributing factors in the nutrient buildup in the lake. Unless nutrients of artificial origin are prevented from entering the lake, troublesome algal conditions will develop to interfere with the recreational and aesthetic uses of the water.

RECOMMENDATIONS

1. Consideration should be given to eliminating the access of nutrients to Silver Lake by retention of all cottage wastes in a manner which will not affect the lake. Until the suitability of septic tank systems in shallow soil-impervious bedrock areas is clarified, human wastes could be disposed of using one of a number of alternatives depending upon the attitudes, objectives and financial status of each individual cottage or home owner. Such alternatives include the use of electric or propane-powered waste disposal units, pit privies well removed from the lake where suitable soil depth and water table conditions exist or holding tanks. The latter requires periodic pumping and trucking of wastes to an adequate

sewage treatment system. A thorough review of existing waste disposal methods in cottage areas as well as research relative to the need for alternatives to existing septic tank systems will hopefully be clarified by studies currently being considered by the Commission. Depending upon the results of these studies, an educational programme may be essential to ensure that cottagers implement adequate controls for cottage wastes and understand the need for and benefits to be derived from action of this type.

2. Preventative measures on the part of individual cottage owners by using phosphorus-free soaps rather than types of detergents which are rich in phosphorus will limit by as much as 50% artificial inputs of nutrients into Silver Lake.

3. A meeting should be arranged between OWRC personnel and cottage owners on Silver Lake. The objectives would be to clarify to the cottagers any misconceptions relative to the state of enrichment of the lake and potential benefits which may be derived from the aforementioned recommendations.

Note: a glossary is provided as Appendix B on page 15 to clarify the meaning of technical and scientific terms.

STATUS OF ENRICHMENT OF SILVER LAKE - 1969

INTRODUCTION

Late in August 1969, the District Engineers Branch of the Division of Sanitary Engineering received a request from cottagers on Silver Lake to provide a statement relative to the degree of enrichment of the lake. Apparently, the request materialized as a result of local support and interest in the eutrophication study which is currently being conducted in the nearby Muskoka lakes. Subsequently, personnel of the Biology Branch carried out a survey on Silver Lake to determine the existing physical and chemical conditions, nutrient levels and corresponding standing stocks of algae to assess the 'trophic-status' of the lake.

GENERAL DESCRIPTION OF THE STUDY AREA

Silver Lake is located in the Township of Medora-Wood, District of Muskoka, approximately $\frac{1}{2}$ -mile southeast of Port Carling (Fig. 1). The lake has an estimated surface area of 130 acres with a maximum depth of 14.4 metres. The watershed consisting of out-wash sands interspersed with pre-Cambrian igneous and metamorphic rock is limited on the north and west by the Indian River, on the east by Arthurlie Bay and on the south by moderately high outcroppings of rock. The lake is apparently spring-fed and drains via a small stream into Mirror Lake, an expanded portion of the Indian River. At the time of the survey flow from Silver Lake to Mirror Lake was negligible. Very few vascular aquatic weeds were observed in near-shore areas although a few water lilies (i.e. Nuphar) and cattails (i.e. Typha) were noted near the south-west shore.

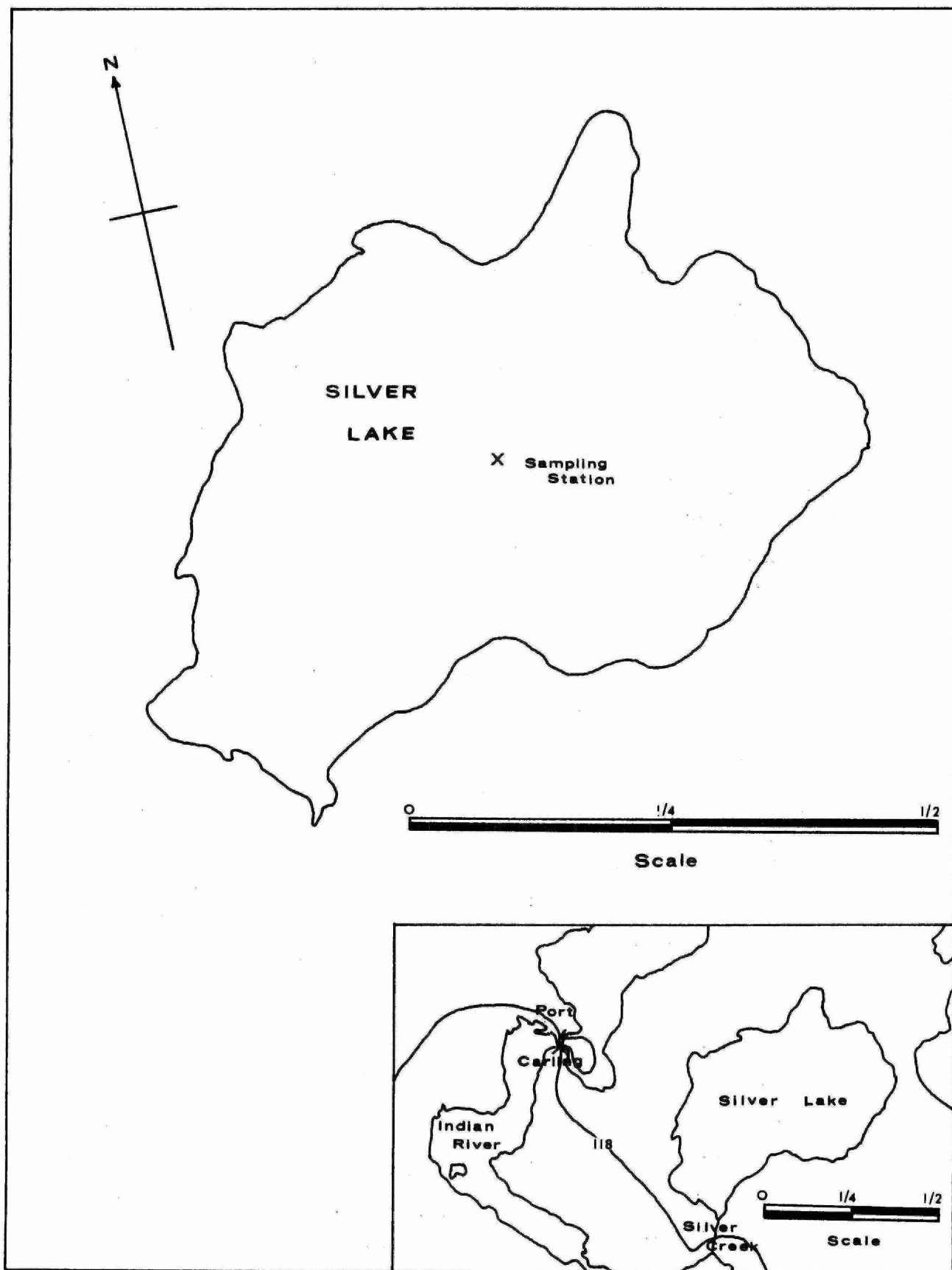


Figure 1. Approximate location of sampling site, Silver Lake. September 3, 1969.

An estimated 45-55 cottages surround Silver Lake with a trailer camp located on the south-western shoreline. Because of time limitations, a cottage-to-cottage assessment of the waste disposal systems was not carried out. However, information from local residents indicated that all cottagers use septic tanks for disposal of human wastes. Sink and laundry wastes are disposed of by leaching pits, septic tanks or by draining the wastes directly onto the ground.

METHODS

Field methods

Physical measurements and sample collections were made on September 3, 1969 at a centrally-located station (Fig. 1) where a maximum depth of 14 metres occurred.

Forty-ounce water samples were collected for biological and chemical analyses with a Van Dorn sampler. Samples for chemical analyses were from 1, 3, 9 and 14 m and for biological analyses were from 1, 3, 6 and 9 m. The latter samples were preserved with Lugol's iodine at the time of sampling. All samples were returned to the Ontario Water Resources Commission laboratories in Toronto for analyses.

Temperature readings were made using a telethermometer. A Secchi disc was used to determine an index of light penetration and pH readings were completed employing an IL Porto-matic pH meter. Dissolved oxygen concentrations were established using the Winkler method. Manganese sulphate, alkaline azide and sulphuric acid re-agents were added in the field while titration with .0045N thiosulphate solution was carried out in the mobile laboratory located at Port Carling. Temperature, pH and dissolved oxygen were measured at each meter of depth.

Laboratory methods

Nutrient analyses were performed on each water sample for nitrogen (Total Kjeldahl and ammonia nitrogen as N),

total phosphorus (as P) and orthosilicate (as SiO_2). Determinations for iron were completed, also. All analyses were conducted following standard procedures (American Public Health Association 1965).

The algal samples were concentrated by allowing the cells (phytoplankton) to settle for 72-96 hours, and the overlying liquid was then syphoned or decanted. Subsequently, the cells were re-suspended in the concentrate and a 1-ml aliquot was transferred into a Sedgwick-Rafter counting cell. All of the algal forms were identified to genus at a magnification of 200X. Numerical results were recorded in areal standard units (a.s.u.) per millilitre. One areal standard unit is equal to an area of 400 square microns (Whipple 1914). An areal value was employed because it is a reliable measurement of the standing stock of phytoplankton (Paasche 1960) and is a useful means of relating algal levels to problems associated with water quality. Depending on the density of the concentrate, strips or fields were counted. To render results statistically accurate, between 150 and 200 organisms per millilitre were identified and measured.

RESULTS

Physical aspects

A well-defined thermocline or zone of rapid temperature change was detected characterized by a decrease in water temperature of 10°C between 6 and 9 m (Fig. 2a).

A Secchi disc reading of 3.8 m indicated a euphotic zone or zone of algal production to a depth of approximately 7.6 m.

Water chemistry

Moyle (1949) considered a total alkalinity of 40 mg/l to be a natural separation point between soft and hard waters. Silver Lake was characterized by a mean alkalinity of 11.5 mg/l.

Percent Saturation (%)

20 40 60 80 100 120 140

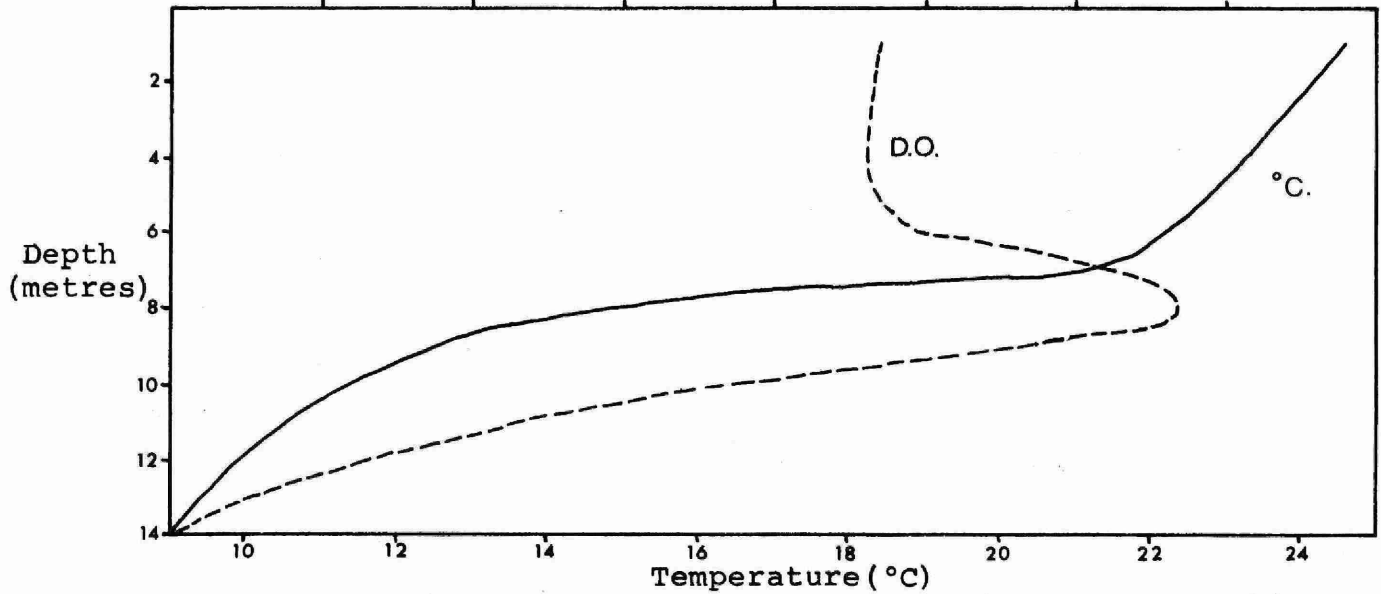


Fig.2a. Profiles of temperature and dissolved oxygen, Silver Lake.

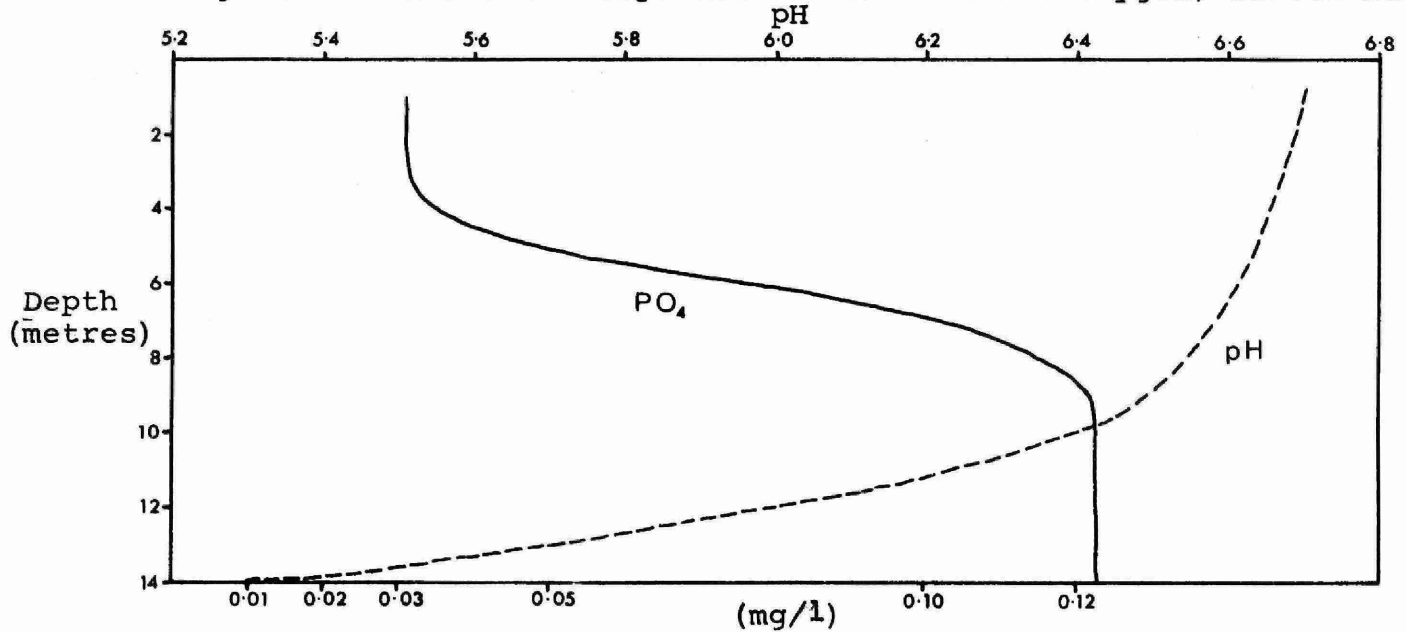


Fig.2b. Profiles of pH and total phosphorus(as PO₄). Silver Lake.

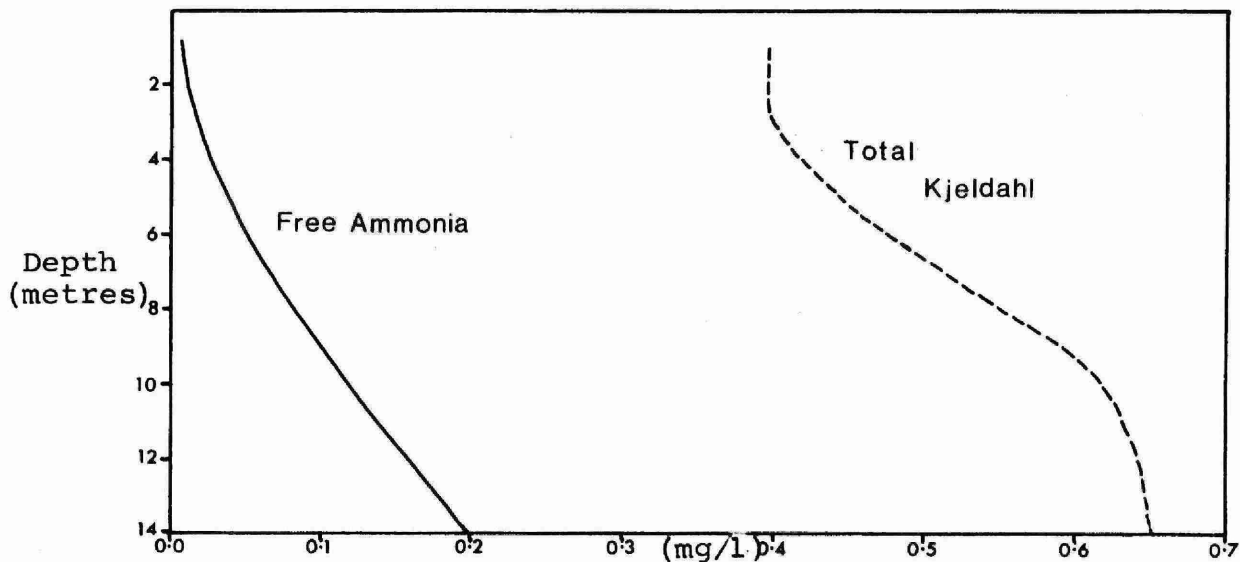


Fig.2c. Profiles of free ammonia and total Kjeldahl nitrogen, Silver Lake, September 3, 1969.

A striking maximum in oxygen concentration developed in the lower portion of the thermocline (Fig. 2a). At 8 and 9 m oxygen saturations up to 135% or 18.2 mg/l were found. This type of oxygen distribution is termed positive heterograde.

The pH in Silver Lake was higher at the surface than in the deeper strata (Fig. 2b).

Total phosphorus concentrations in the hypolimnion (zone of colder water below the stable thermocline) were considerably higher than those recorded from the warmer epilimnion (above-thermocline) waters (Fig. 2b). At this point it is significant to note that iron concentrations (as Fe) increased from 0.00 mg/l at 1, 3 and 6 m to 0.14 mg/l at 14 m. Total Kjeldahl and free ammonia in Silver Lake were slightly higher in the hypolimnion than in the epilimnion (Fig. 2c).

No definite pattern in the distribution of ortho-silicate was apparent with depth, as concentrations ranged between a low of 0.5 mg/l and a high of 1.2 mg/l at 14 and 3 m, respectively.

Phytoplankton populations

In Silver Lake algal levels increased from 1,530 a.s.u. per ml at 1 m and 3 m to 1,885 a.s.u. per ml at 6 m to 4,660 a.s.u. per ml at 9 m (Fig. 3). All samples were dominated by high levels of blue-green algae. The dominant alga in the upper six metres was Chroococcus (i.e. 882-1,119 a.s.u. per ml) whereas at 9 m Anabaena dominated (i.e. 1,867 a.s.u. per ml). The sub-dominant alga at all depths was Aphanothece, another blue-green. Low to moderate numbers of flagellated and green algae were reported from all depths. Diatoms were not encountered in the samples examined. A detailed qualitative and quantitative summary of the phytoplankton in Silver Lake on September 3, 1969 is provided in the Appendix.

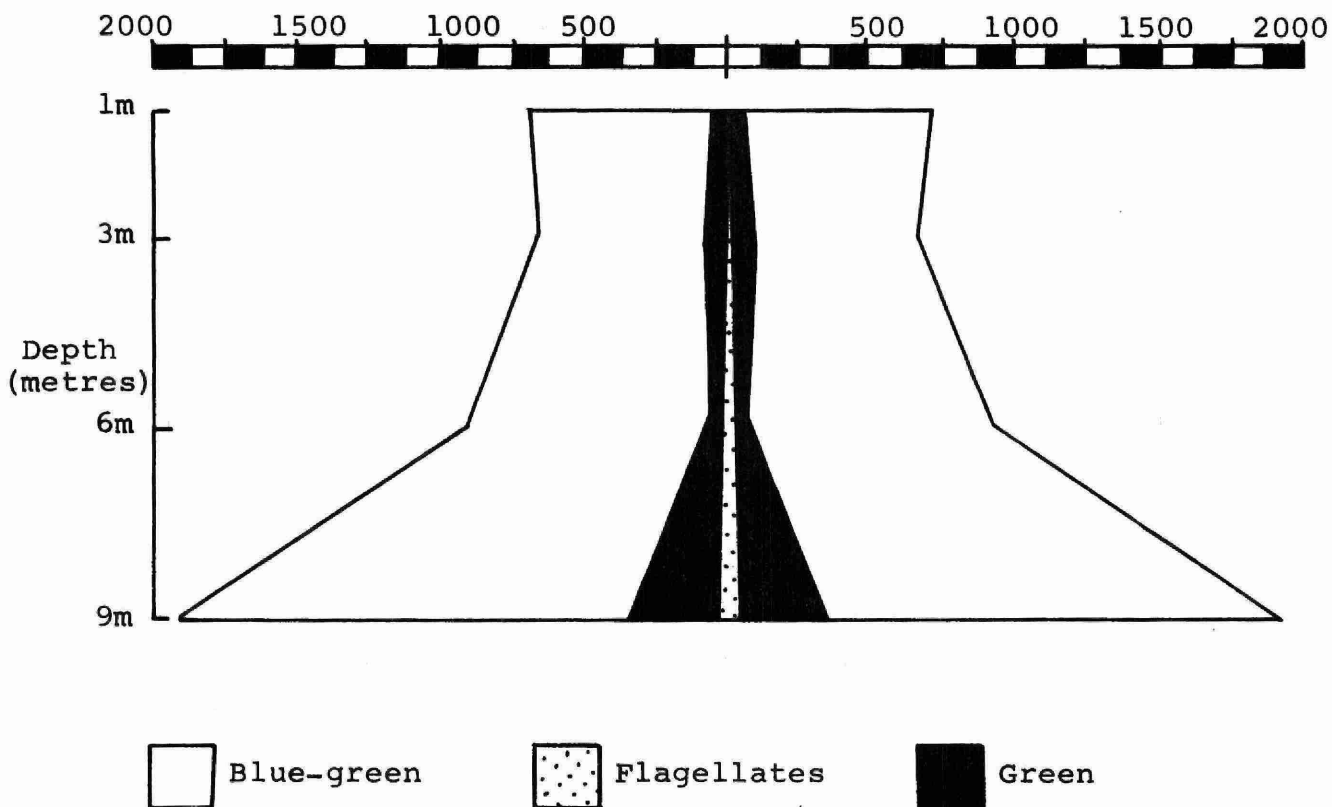


Fig. 3. Standing stocks of phytoplankton at a centrally located station in Silver Lake, September 3, 1969. Results are expressed as areal standard units per millilitre.

DISCUSSION

Status of enrichment in Silver Lake

Lakes of north temperate regions have been classified trophically as oligotrophic, mesotrophic and eutrophic. Oligotrophic or 'nutrient-poor' lakes are generally deep, clear, unproductive and support coldwater species such as lake trout, whitefish and herring. Eutrophic lakes are usually turbid, warm, productive and contain warmwater game fish species such as walleye, pike, perch and other less valued species, for example catfish and carp. Lakes of intermediate type are termed mesotrophic. The transition from oligotrophic to eutrophic lakes progresses naturally owing to inputs of sediments and dissolved minerals associated with land run-off. These materials are retained and increase the nutrient potential of the lake. The impact of sedimentation and gradual increases in levels of soluble phosphate, nitrate, calcium, silica, manganese and other mineral salts on phytoplankton production in a lake varies with climatic conditions, the shape and size of the lake basin, thermal conditions in the lake and colour and turbidity (which affects light penetration and hence the depth of the euphotic zone). As the lakes become shallower and warmer and levels of plant nutrients increase, they support increased phytoplankton populations, and attached forms of algae and vascular aquatic vegetation may develop. The lake is then in a eutrophic or enriched state. With time, decomposition products from the biota (living matter) and accumulations from inflowing tributaries fill the lake basin so that the lake takes on the physical and biological characteristics of a swamp or marsh-land. Generally, eutrophication is a slow process measured in geological time. However, it can be dramatically accelerated by artificial inputs from domestic and industrial wastes and agricultural run-off. In most lakes of significant size, it is unlikely that the progression from oligotrophy to eutrophy will occur in a single generation of man. However, in lakes

severely affected by artificial inputs of nutrients, classical indications of mesotrophy and/or eutrophy (for example, changes in benthic and planktonic abundance; species production and community associations; nutrient and dissolved oxygen concentrations; sediment types; fish production etc.) will appear over relatively short-term periods.

The following briefly outlines how quantitative and qualitative parameters were used to assess the status of enrichment in Silver Lake.

Secchi disc readings are dependent upon the quantity or particulate suspended material (i.e. microscopic plants, silt, etc.) and coloured matter (i.e. humus, tannins, etc.) in the water. In comparison to Silver Lake where a Secchi disc reading of 3.8 m was recorded, readings in oligotrophic Lake Joseph on September 3, 1969 and in eutrophic Riley Lake (located approximately 12 miles south east of Gravenhurst) on September 2, 1969 were 7.6 m and 1.4 m respectively. The primary factor contributing to differences in light penetration between the three lakes can be related to differences in phytoplankton abundance.

The positive heterograde oxygen distribution or metalimnetic maximum in Silver Lake resulted from optimum photosynthesis in the lower portion of the thermocline. This particular type of distribution in late summer is similar to that reported from a number of small mesotrophic lakes in Indiana (Eberly 1959, 1963, 1964; Wetzel 1966), Austria (Findenegg 1963, 1964) and Minnesota (Baker et al. 1969), all of which are generally protected from wind action as is Silver Lake.

The higher pH values in the surface waters (when compared with those in the hypolimnion) resulted from the reduction of free CO₂ and calcium bicarbonate during photosynthesis. The decrease in pH in hypolimnetic waters was related to conditions of decomposition with corresponding CO₂ and calcium bicarbonate increases.

The increases in free ammonia and Total Kjeldahl nitrogen (Fig. 2c) in the hypolimnion are characteristic of mesotrophic and eutrophic lakes. These increases are caused by bacterial decomposition and/or reduction processes.

The vertical distribution of phosphorus during thermal stratification is quite different in nutrient-poor and productive lakes. In the former type of lake, relatively little variation exists with depth in total phosphorus. In contrast, the hypolimnetic waters of productive lakes such as Silver Lake are characterized by an increase in the total phosphorus (Fig. 2b) owing mainly to sedimentation of plankton (Steiner, 1938).

The main phytoplankters in Silver Lake were represented by the blue-greens Chroococcus, Aphanothece and Rhabdoderma with the exception of high numbers of Anabaena which were found at 9 m. The presence of many species of blue-green algae similar to those of Silver Lake have been reported from Dunlop Lake (Johnson, Michalski and Christie 1970), a mesotrophic lake located near Elliot Lake. Considering the composition of phytoplanktonic communities, it is apparent that Silver Lake is mesotrophic.

The mesotrophic lakes of Eberly (1959, 1963, 1964), Wetzel (1966), Findenegg (1963, 1964) and Baker et al. (1969) were characterized by a maximum development of Oscillatoria spp. within the thermocline (metalimnion). In contrast, the metalimnetic increase in standing stocks of phytoplankton in Silver Lake was due to the abundance of Anabaena and Aphanothece (Anabaena was virtually absent from samples taken closer to the surface). Optimum development of Anabaena and Aphanothece at 9 m may be related to their preference or requirement for colder temperatures (Fig. 2a), higher nutrient concentrations (Fig. 2b and 2c), lower light intensities or a combination of these factors.

Sources of nutrients in Silver Lake

In lakes remote from human influence, natural sources of plant (algal) nutrients are the atmosphere, precipitation, ground water, runoff from the surrounding drainage area and natural exchange from lake sediments. Each of these sources contributes carbon, phosphorus and nitrogen which are considered to be the major growth-stimulating plant nutrients. Although micro-nutrients or trace elements such as iron, cobalt, nickel and molybdenum, organic materials and vitamins are required for growth (Menzel and Ryther 1961, Goldman 1960, Goldman 1964 and Goldman and Carter 1965) there is usually no deficiency of these in the aquatic environment. With the development of cottages around Silver Lake, artificial inputs of carbon, phosphorus and nitrogen from kitchen and laundry wastes and seepage from septic tanks have undoubtedly contributed to the nutritional buildup in the lake.

Probably one of the major nutrient sources into Silver Lake has been through the use of household detergents since these products may contain up to 50% by weight, phosphorus as PO_4 . Phosphorus originating from detergents may gain access to the lake following dishwashing and laundering activities. Although *Anabaena* spp. is reported to fix atmospheric nitrogen (Hutchinson 1957), fixation by this species may be negligible owing to its vertical distribution in the lake. It should be emphasized that once nutrients enter a lake, loss of these substances through inflow-outflow exchange may be almost negligible. In Silver Lake considering the limited outflow over much of the year, nutrients gaining access to the lake tend to accumulate and thereby increase the productive capacity of the lake.

Traditionally, cottagers think of pollution in terms of bacteria and related public health problems. However, the development of high numbers of algae and aquatic plants may be a more serious threat relative to the multi-use potential of a lake. The installation of efficiently functioning septic tanks can be highly effective in curbing

bacterial pollution but may not be effective in limiting access of nutrients to a lake.

How much of the current production in Silver Lake can be attributed to artificial enrichment is open to question; nonetheless, it is safe to say that nutrients from domestic wastes have contributed significantly to the overall nutrient buildup. It should be emphasized that the indications of mesotrophy reveal that Silver Lake is progressing at an accelerated rate to a condition where troublesome algal conditions will interfere with recreational and aesthetic uses of the water.

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APPENDIX A

Table 1. Summary of phytoplankton data at four depths at the sampling station in Silver Lake, September 3, 1969. All results are recorded in areal standard units per millilitre.

Depth (metres)	1	3	6	9
Blue-greens				
<u>Anabaena</u>	4	16	167	1867
<u>Aphanizomenon</u>	p*		p	
<u>Aphanothece</u>	249	497	507	1612
<u>Chroococcus</u>	1119	822	1026	261
<u>Dactylococcopsis</u>	1	1	10	
<u>Lyngbya</u>	4	12	7	
<u>Rhabdoderma</u>	29	19	87	82
Flagellates				
<u>Chlamydomonas</u>		1	1	86
<u>Cryptomonas</u>	4	7	23	60
<u>Peridinium</u>	p			
<u>Trachelomonas</u>			5	8
Greens				
<u>Arthrodesmus</u>	p			
<u>Botryococcus</u>	20	21	8	
<u>Mougeotia</u>	98	121	42	89
<u>Scenedesmus</u>	1	2	3	599
<u>Staurastrum</u>		5		
<u>Tetraedron</u>		1		
Diatoms				
<u>Nitzschia</u>	2			
Total a.s.u. per ml.	1,531	1,525	1,886	4,664

p* = present = less than .5 a.s.u. per ml.

APPENDIX B

Glossary of terms

ALGAE - an assemblage of simple, mostly microscopic non-vascular plants containing photosynthetic pigments such as chlorophyll. Algae occur suspended in water (phytoplankton) and as filaments attached to rocks and other substrates. Some algae may produce nuisance conditions when environmental conditions are suitable for prolific growth.

BIOTA - all living organisms in a region.

BLUE-GREEN ALGAE - a group of algae with a blue-pigment, in addition to the green pigment - chlorophyll. A foul odour is often associated with the decomposition of dense 'water-blooms' of blue-green algae in fertile lakes.

DIATOMS - one of the most important groups of microscopic algae found in freshwater. Diatoms are distinguished by their silica cell walls (consisting of two halves, one fitting into the other like a box and its lid) and by their yellow or brown colour.

DISSOLVED OXYGEN - atmospheric oxygen which is dissolved in water and can be expressed as parts per million or percent saturation.

EPILIMNION - the uniformly warmer and turbulent superficial layer of a lake when it is thermally stratified during the summer. The layer above the thermocline(Fig.4).

EUPHOTIC ZONE - the lighted region that extends vertically from the water surface to the level at which photosynthesis fails to occur because of ineffective light penetration.

EUTROPHICATION - the process of progressively becoming more eutrophic with increasing enrichment in the supply of plant nutrients. It refers to the whole complex of changes which accompanies increasing enrichment with plant nutrients. The end result is always the same; the production of dense nuisance growths of algae and aquatic weeds which generally degrade water quality and render the lake useless for many purposes.

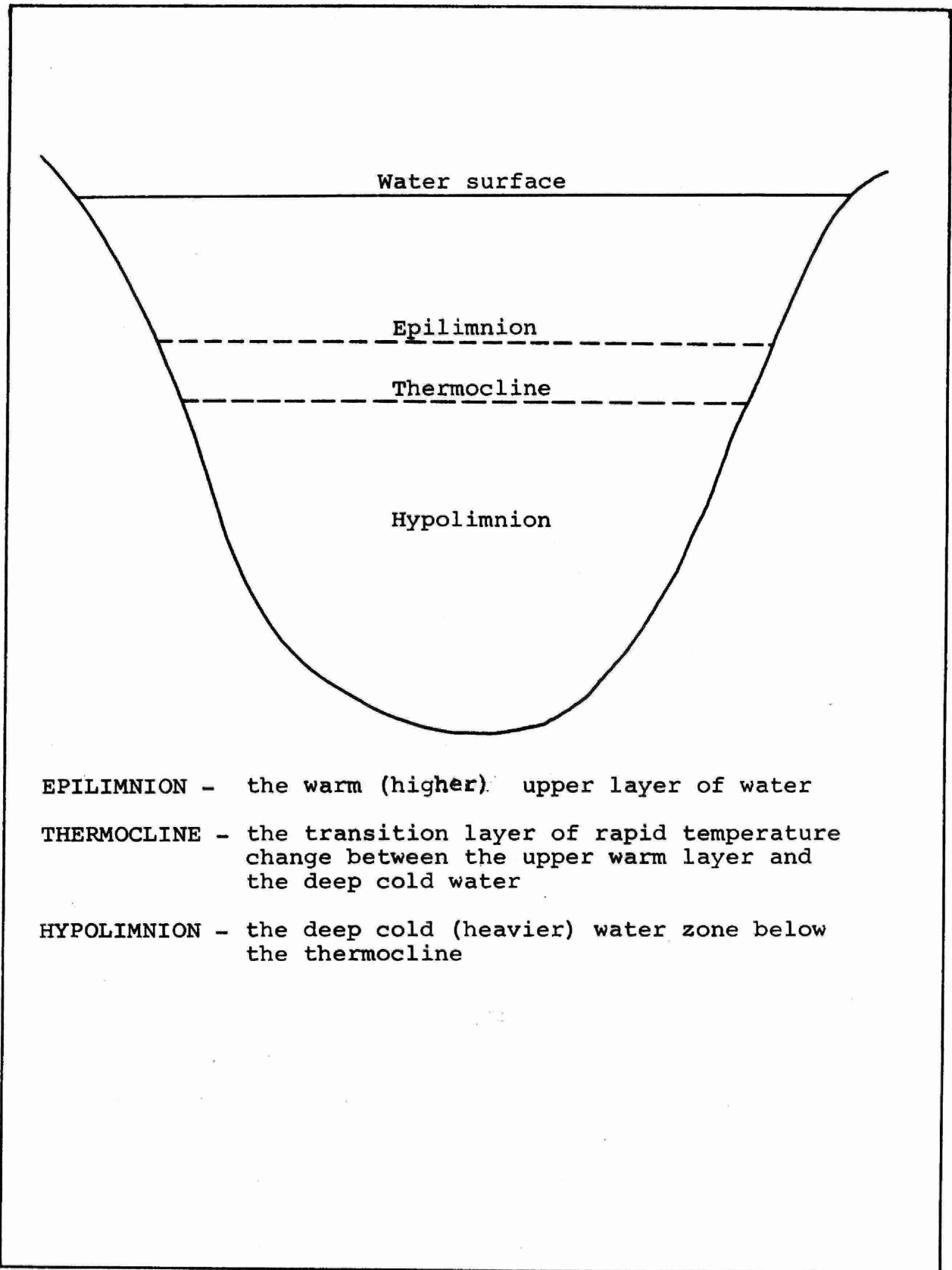


Fig. 4. Section of Silver Lake on September 3, 1969, showing the three layers resulting from thermal stratification.

FLAGELLATED ALGAE - a group of algae which have one or more whip-like appendages (flagella) per cell. The flagella are used for movement.

GREEN ALGAE - a group of algae which have pigments similar in colour to those of higher green plants.

HYPOLIMNION - the uniformly cold and deep layer of a lake when it is thermally stratified during the summer. The hypolimnion is below the thermocline (Fig.4) and is generally removed from surface influence (i.e. does not receive oxygen from the atmosphere).

LUGOL'S IODINE - a preservative for algae containing potassium iodide, iodine and water.

M - metre

METALIMNION - see THERMOCLINE

MICRON - a unit of measurement equal to 0.001 millimetres.

ML - millilitre

ORTHOSILICATE - silica in water is detected as orthosilicate. Silica is present in natural waters in soluble and colloidal forms. A silica cycle occurs in many bodies of water containing organisms, such as diatoms which utilize silica in their skeletal structure. The silica removed from the water by the diatoms may be slowly returned by re-solution of the dead organisms.

pH - a means of expressing the degree of acidity or basicity of a solution. At normal temperature, neutral solution such as pure distilled water has a pH of 7, a basic solution has a pH greater than 7 and an acidic solution has a pH less than 7.

PHOTOSYNTHESIS - the process by which simple sugars are manufactured from carbon dioxide and water by living plant cells with the aid of chlorophyll in the presence of light.

PHYTOPLANKTON - free-floating microscopic algae which are slightly motile and exist at or near neutral bouyancy.

PLANKTON - an assemblage of micro-organisms, both plant and animal, that either have relatively small powers of locomotion or drift in the water subject to the action of waves and currents.

SECCHI DISC - a circular metal plate, 20 centimetres in diameter, the upper surface of which is divided into four equal quadrants and so painted that two quadrants directly opposite each other are black and the intervening ones white. The Secchi disc is used to estimate the depth of the euphotic zone.

SEDGWICK-RAFTER COUNTING CELL - a plankton-counting cell consisting of a brass or glass receptacle 50 x 20 x 1 millimetres sealed to a 1 x 3 inch glass microscope slide. A rectangular cover glass large enough to cover the whole cell is required. The cell has a capacity of exactly 1 millilitre.

STANDING STOCK - the biota present in an environment at a selected point in time.

THERMAL STRATIFICATION - in the spring, vertical temperatures in a lake or reservoir are homogeneous from top to bottom. As summer advances, the surface waters become warmer and lighter than the underlying colder, denser waters. A thermal gradient or stratification is established in which various water layers can be defined (Fig. 4).

THERMOCLINE - the transition layer (Fig. 4) of rapid temperature change between the upper warm water layer and the cold deep-water layer. It is usually defined by a change in temperature of 1°C for each metre of water depth.

TROPHIC STATUS - depending on the degree of plant nutrient enrichment and resulting biological productivity, lakes are generally classified into three intergrading types: oligotrophic, mesotrophic and eutrophic. If the supply of plant nutrients to an extremely oligotrophic lake is progressively increased, the lake will become more mesotrophic in character; with further enrichment it will eventually become eutrophic.



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